Methods to Conduct an Approximate
Community Coastal Flood Threshold Analysis

Summary of Process Steps

1. Visually determine critical flood elevation thresholds
2. Convert thresholds between tidal and vertical datums and convert feet to meters
3. Determine return periods
4. Investigate how sea level rise will change return periods
5. Determine when thresholds will be permanently exceeded (permanent inundation)
6. Determine the derived high tide threshold and how many high tide flooding days occur now
7. Calculate the number of high tide flooding days that will occur under different sea level scenarios in the future
8. Determine the current 1 percent water level (100 year). Learn how to calculate how much water level increase will cause the 1 percent chance to become the 10 percent chance water level event (10 year). Find out when this will happen, based in different sea level rise scenarios.
9. Estimate exposure of your community to FEMA 1 percent annual-chance floodplain (100-year or special flood hazard area) and more severe storm surge flooding

Populate table with your findings and use the information to fill in blanks and create your final report.

Tools to Use

- NOAA Center for Operational Oceanographic Products and Services (CO-OPS) Extreme Water Level Analysis
- NOAA Sea Level Rise Viewer
- U.S. Army Corps of Engineers Sea Level Rise Calculator
- NOAA Tech Report for High Tide Thresholds (formatted spreadsheet)
- NOAA Coastal Flood Exposure Mapper

Process Step 1: Visually determine critical flood elevation thresholds

- ❑ Open a web browser and navigate to the NOAA Sea Level Rise Viewer at coast.noaa.gov/slr.
- ❑ Click on the **Get Started** button. The default tab is the sea level rise tab.

- ❑ Type in your area of interest (state, city, address) in the search bar at the top. Zoom in to the scale that allows you to view the area of interest.
- ❑ Use the slider bar to raise water levels from current mean higher high water (MHHW) in 1 foot increments up to 6 feet above MHHW.
- ❑ Green areas denote lower areas not connected by surface hydrology to the ocean, but they can eventually become connected as the water levels are raised. These areas are typically low-lying, flood-prone areas.
- ❑ Do a visual analysis of when inundation (shades of blue indicate relative depth) becomes an issue for your location. Note the amount of inundation by looking at the slider bar and recording the number in the table under "Current Threshold (feet MHHW)." (e.g., 3 feet MHHW)

Process Step 2: Convert thresholds between tidal and vertical datums and convert feet to meters

- ❑ Determine the closest NOAA tide gauge to your location. Click the **Local Scenarios** tab and click on the closest scenario location. Make note of the name of the tide gauge and the location. (e.g., Charleston, SC)
- ❑ Open a new window in your browser. Go the CO-OPS web page at tidesandcurrents.noaa.gov and click on the same gauge location icon in the map (e.g., Charleston, Cooper River Entrance). When the pop-up box comes up, select "Datums."
- ❑ On the datums page, subtract the North American Vertical Datum of 1988 (NAVD88) value from the MHHW value. This provides the difference between the two datums and allows the conversion of the threshold value determined above from MHHW to NAVD88. This value is important and is needed when working with other data, such as first floor elevations and stormwater inlets and outfalls. To accomplish this task, add the difference just calculated to the threshold value from above. For example, a difference of 2.62 between MHHW and NAVD88, plus a 3 foot threshold, equals 5.62 feet. This means that a 3 foot MHHW threshold is equal to 5.62 feet NAVD88 for that tide gage. Record this NAVD88 value in the table. (e.g., 5.62 feet NAVD88)
- ❑ Now convert both the feet MHHW value and feet NAVD88 value to meters (1 foot = 0.3048m;) (e.g., 0.9m MHHW and 1.71m NAVD88). You will need these numbers in later steps. Report these numbers in the table.

Process Step 3: Determine return periods

CO-OPS Extreme Water Level Data

- [ ] Now open the web browser and navigate to the tides and currents extreme water level analysis page at *tidesandcurrents.noaa.gov/est*. Zoom in on the map and click on the same tide gauge you used to convert datums (e.g., Charleston, SC). In the pop-up, click on **Exceedance Probability Curves**.
- [ ] Use the top graph referenced to MHHW to estimate the return period in years that coincides with your chosen threshold (e.g., 0.9 m is approximately 20 years on X-axis. Each tick on the X-axis is 10 years). Record this number in the table under "Current Return Period (years)."
- [ ] Divide 1 year by the number of years from above to calculate the percent chance of exceedance within a given year. (e.g., 1/20 = 0.05 or 5 percent). Record this number in the table "current return period (percent per year).

U.S. Army Corps of Engineers Sea Level Rise Calculator

- [ ] Now open your web browser and navigate to this tool: *corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html*. Scroll down and select your tide gauge name from the drop-down list (e.g., Charleston, SC). Then scroll down to the "Tidal Datums" and "Extreme Water Levels" table and graph. Notice the default datum is height above NAVD88 and the default output units are in feet.
- [ ] Use the table on the left to estimate the return period in years that coincides with your chosen threshold in NAVD88 feet. Round to the nearest return period year value. (e.g., 5.62 feet can be rounded to 5.67 feet, which is equivalent to the 20 year return period)
- [ ] Divide 1 year by the number of years from the above step to calculate the percent chance of exceedance within a given year (e.g., 1/20 = 0.05 or 5 percent)

A note regarding tide gauge data and waves

The extreme levels measured by the tide gauges during storms are called storm tides, which are a combination of the astronomical tide, storm surge, and limited wave setup caused by breaking waves. These levels do not include wave runup, the movement of water up a slope. Therefore, the 1 percent annual exceedance probability levels shown on this website do not necessarily correspond to the base flood Elevations defined by the Federal Emergency Management Administration (FEMA), which are the basis for the National Flood Insurance Program. The 1 percent annual exceedance probability levels on this website more closely correspond to FEMA's still water flood elevations. The peak levels from tsunamis, which can cause high-frequency fluctuations at some locations, have not been included in this statistical analysis because of their infrequency during the periods of historic record.

Process Step 4: Investigate how sea level rise will change return periods

CO-OPS Extreme Water Level Page

- ❑ Return to the return period graph and estimate what water level corresponds to the 2 year event, or 50 percent per year).
- ❑ Subtract the chosen threshold from this water level and record the value in the table. (e.g., 0.9 m – 0.6 m = 0.3 m). This is the amount of sea level that will cause the chosen flood threshold to be exceeded once every 2 years, or a 50 percent chance in a given year.
- ❑ Convert this number to feet as well (e.g., 0.3 m = 0.98 ft, or 1 ft rounded). Record this number in the table.

Corps of Engineers Calculator

- ❑ Return to the return period table and estimate what water level corresponds to the 2 year event, or 50 percent per year (e.g., 4.47 feet).
- ❑ Subtract the previously calculated 20 year threshold from this water level and record the value in the table (e.g., 5.67 ft - 4.47 ft = 1.2 ft). Record this number in the table.
- ❑ Convert this number to meters as well (e.g., 1.2 ft = 0.37 m). Record this number in the table.

Process Step 5: Determine when thresholds will be permanently exceeded (permanent inundation)

- ❑ Open your web browser and go to the Corps of Engineers' sea level rise calculator tool (*corpsclimate.us/ccaceslcurves.cfm*). This tool can be used to determine when critical elevations will be exceeded using multiple sea level rise scenarios. The tool has many sea level rise scenarios from various scientific reports to choose from. The most recent science for sea level rise projections is the NOAA 2017 scenarios (used for the Fourth National Climate Assessment, Climate Science Special Report, and included in the NOAA Sea Level Rise Viewer tool under the "local scenarios" tab).
- ❑ Choose the same tide gauge location as above from the Select Gauge drop-down menu (e.g., Charleston, SC); then select the NOAA et al. 2017 scenarios from the Scenarios Source drop-down.
- ❑ In the Critical Elevation #1 (ft) box, type in the initial critical threshold in MHHW from above (e.g., 3 feet MHHW).
- ❑ Check the **Adjust to MSL (83-01) Datum** box and select **Interpolated** from the Lines Type menu.

- ❑ Scroll down to view the generated chart and table to approximate when the 3 foot line will be crossed by the 6 scenario curves. (Record these years in the table.)
- ❑ Charleston example:
  - ❑ NOAA Extreme – 2048
  - ❑ NOAA High – 2053
  - ❑ NOAA Int-High – 2063
  - ❑ NOAA Intermediate – 2080
  - ❑ NOAA Int-Low – n/a
  - ❑ NOAA Low – n/a
- ❑ Notice the selected threshold does not get exceeded by lower scenarios.
- ❑ The chosen threshold will become the future MHHW line for these years based on the scenario. The NOAA extreme scenario, for example, will be 30 years from 2018.

Understanding the Scenarios

The six relative sea level rise scenarios shown in this tab are derived from NOAA Technical Report NOS CO-OPS 083: Global and Regional Sea Level Rise Scenarios for the United States using the same methods as the U.S. Army Corps of Engineers Sea Level Rise Calculator. These new scenarios were developed by the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force, jointly convened by the U.S. Global Change Research Program and the National Ocean Council as input to the USGCRP Sustained Assessment process and Fourth National Climate Assessment. These relative sea level rise scenarios provide a revision to the (Parris et. al, 2012) global scenarios that were developed as input to the Third National Climate Assessment.

These relative sea level rise scenarios begin in year 2000 and take into account global mean sea level rise, regional changes in ocean circulation, changes in the Earth's gravity field due to ice melt redistribution, and local vertical land motion.

A relative sea-level-rise adjustment to the current National Tidal Datum Epoch (1983-2001) will cause a minimal offset that may be needed for some applications. The Corps of Engineers' sea level rise calculator can correct for this offset.

For almost all the scenarios, relative sea level rise is likely to be greater than the global average in the U.S. Northeast and the western Gulf of Mexico. In intermediate and low scenarios, relative sea level rise is likely to be less than the global average in much of the Pacific Northwest and Alaska. For high scenarios, relative sea level rise is likely to be higher than the global average along all U.S. coastlines outside Alaska.

Process Step 6: Determine the derived high tide threshold and how many high tide flooding days occur now

- ❑ Download this Excel spreadsheet ("Patterns and Projections of High Tide Flooding").

- ❑ Search for and type in the name of the tide gauge you have been using (e.g., Charleston, SC – Row AX). Go to row 13. This is the derived high-tide threshold, in meters, used by NOAA to count the number of high tide flooding days. Record this number in the table (e.g., 0.57 m MHHW).
- ❑ Convert the high tide threshold to feet and to NAVD88 meters and feet, and enter into the table. (e.g., 1.9 ft MHHW, 4.52 ft NAVD88, 1.37 m NAVD88).

- ❑ Search for and type in the name of the tide gauge you have been using (e.g., Charleston, SC – Row AX). On the **floodshistorical** tab, scroll down to the 2016 date row (this is the last row and last date of recorded high tide flooding).
- ❑ Record this number in the table under “High Tide Events (days/year).” (e.g., 6).

Process Step 7: Calculate the number of high tide flooding days that will occur under different sea level scenarios in the future

- ❑ In the same Excel spreadsheet, click on the **extreme scenario** tab. Search for the tide gauge column you are using (e.g., Charleston, SC – Row AX).
- ❑ To find out how many days high tide flooding will happen at this location, choose the number of high tide flooding days that would be critical (e.g., half the year would be 183 days) and record in the table under “Planning Timeframe.” Scroll down until you find the row that exceeds 185; then scroll over to see the year. Record this year and days in the table. (e.g., row 42 shows 193 flood days which corresponds to 2036) That means in this example, under the extreme sea level rise scenario in Charleston, by 2036 the high-tide threshold will be exceeded over half the year.
- ❑ Repeat the above steps for each of the sea level rise scenarios for your tide gauge and for each scenario, and populate the table with the number of days and the scenario year your planning timeframe (number of days per year) is exceeded.
- ❑ If you only need to consider a couple of sea level rise scenarios, then only do this for those you have selected. The same procedure can be used each time.
- ❑ When does the high tide flooding move from the “nuisance” category to the more serious situation where permanent impacts occur? Determining how many days of high tide flooding constitutes an issue is a judgment to be made by the local community.

Process Step 8: Determine the current 1 percent water level (100 year). Learn how to calculate how much water level increase will cause the 1 percent chance to become the 10 percent chance water level event (10 year). Find out when this will happen within different sea level rise scenarios.

- ❑ Open the web browser and navigate to the tides and currents extreme water level analysis page at *tidesandcurrents.noaa.gov/est*. Zoom in on the map and click on the same tide gauge you used to convert datums (e.g., Charleston, SC). In the pop-up, click on **Exceedance Probability Levels**.
- ❑ This graphic shows several annual exceedance probabilities that are based on historical data collected at this gauge. The 1, 10, 50, and 99 percent probabilities are shown. Locate the 1 percent chance number, which will be in mean sea level (MSL) meters, and record in the table under "1% chance water level (m MSL)." Use the left-hand numbers for the current tidal epoch (1983-2001).
- ❑ Go to the datum page for your gauge again and calculate the difference between MSL and MHHW to convert to the value to MHHW (1 percent MSL value – [MHHW datum - MSL datum]). Once you have done this, also convert it to feet. Record these numbers in the table. For example (2.17 m MSL - 0.867 = 1.303 m MHHW) (2.17 m MSL – 0.067 = 2.103 m NAVD88); convert meters to feet (1.303 m MHHW = 4.27 ft MHHW) (2.103 m = 6.9 ft NAVD88)
- ❑ Do the same thing for the 10 percent water level number and record that in the table.
- ❑ Subtract the 1 percent and 10 percent levels in feet MHHW. Record this amount in the table. This is the amount of water level increase to make the 1 percent become 10 percent (e.g., 1.64 ft).
- ❑ Open the web browser and navigate to the Corp of Engineer's sea level rise calculator. Follow steps from above, but enter the water level from the previous step that will make the 1 percent become 10 percent as the critical elevation.
- ❑ Determine when each of the sea level rise scenarios will cross this water level and record the years in the table.

Process Step 9: Estimate exposure of your community to FEMA 1 percent annual-chance floodplain (100-year or special flood hazard area) and more severe storm surge flooding

- ❑ Open web browser and navigate to the NOAA Digital Coast's Coastal Flood Exposure Mapper. Select the state and county of interest. Click on **FEMA Flood Zones**. Visualize the flooding area relative to the total area of the county and estimate the percentage of the county that is in the floodplain. Record this number (e.g., 75 percent).
- ❑ Click on the **Storm Surge** layer. This displays hurricane storm surge from the National Storm Surge Risk map for category 1-5 storms (1-4 north of North Carolina). This is a worst-case inundation area for evacuation planning purposes, but shows the areas outside the FEMA special flood hazard area that still could be impacted from an extreme storm surge event.

- ❑ Estimate the percent of the county you chose that is covered by the storm surge layer relative to the whole county area. Record this number in the table (e.g., 90 percent).

Template Table

Use the template table to populate your community's basic coastal flood threshold analysis. The highlighted colors in the table correspond to the same colors in the report template below.

Defining the Threshold

Current Threshold (FT MHHW)	Current Threshold (FT NAVD88)	Current Threshold (m MHHW)	Current Threshold (m NAVD88)
3	5.62	0.9	1.71

Changing Return Periods

Current Return Period (years)	Current Return Period (% per year)	Amount of sea level rise (SLR) to cause 2-year return (m)	Amount of SLR to cause 2-year return (ft)
20	5%	0.37	1.2

The Threshold Becomes the Norm

Low Scenario (year)	Intermediate-Low Scenario (year)	Intermediate Scenario (year)	Intermediate High Scenario (year)	High Scenario (year)	Extreme Scenario (year)
n/a	n/a	2080	2063	2053	2048

When High Tide Flooding Becomes a Problem

High tide threshold (ft MHHW)	High tide threshold (ft NAVD88)	High tide threshold (m MHHW)	High tide threshold (m NAVD88)
1.9	4.52	0.57	1.37

High tide events (days/year)	Planning time frame (days/year)
6	183

Low (days/year, scenario year)	Intermediate Low (days/year, scenario year)	Intermediate (days/year, scenario year)	Intermediate High (days/year, scenario year)	High (days/year, scenario year)	Extreme (days/year, scenario year)
n/a	185/2095	190/2059	186/2049	185/2039	193/2036

Significant Flooding Occurring More Often

1% chance water level (feet MHHW)	1% chance water level (feet NAVD88)	1% chance water level (meters MHHW)	1% chance water level (meters NAVD88)	1% chance water level (meters MSL
4.27	6.9	1.303	2.1	2.17

10% chance water level (feet MHHW)	10% chance water level (feet NAVD88)	10% chance water level (meters MHHW)	10% chance water level (meters NAVD88)	10% chance water level (meters MSL

2.63	5.3	0.803	1.603	1.67

Low (year)	Intermediate Low (year)	Intermediate (year)	Intermediate High (year)	High (year)	Extreme (year)
2100	2077	2051	2040	2034	2031

Community Coastal Flood Threshold Analysis (Report Template)

Colors in the report correspond to the template table above.

Defining the Threshold

Charleston, SC, has a critical flood threshold of _3_ ft Mean Higher High Water (MHHW), which represents the water level at which flooding becomes a problem. Another way to refer to this threshold is 5.62 ft North American Vertical Datum of 1988 (NAVD88), which is the datum for elevation data, surveying, and data such as first floor elevations. In addition, these numbers, in meters, are 0.9_m MHHW and 1.71_m NAVD88.

Changing Return Periods

The current return period for this water level, based on historical data, is _20_ years, which has a _5_% chance of occurring in any given year. In the future, it will take 1.2 ft (0.37 m) of water level increase from sea level rise to change the current 20 year return period (or 5% per year) to a 2 year (50% per year) return period.

The Threshold Becomes the Norm

As sea level rises, critical thresholds will be reached by the average highest tides (MHHW), causing daily impacts. This will happen sooner under higher sea level rise scenarios.

- Under the **Low** sea level rise scenario, your critical threshold of _3_ft above MHHW will still be above the future MHHW in 2100 n/a.
- Under the **Intermediate Low** sea level rise scenario, your critical threshold of _3_ft above MHHW will still be above the future MHHW in 2100 n/a.

- Under the **Intermediate** sea level rise scenario, your critical threshold of _3_ft above MHHW will become the new MHHW in 2080.
- Under the **Intermediate-High** sea level rise scenario, your critical threshold of _3_ft above MHHW will become the new MHHW in 2063.
- Under the **High** sea level rise scenario, your critical threshold of _3_ft above MHHW will become the new MHHW in 2053.
- Under the **Extreme** sea level rise scenario, your critical threshold of _3_ft above MHHW will become the new MHHW in 2048.

NOTE: This analysis is based on sea level rise curves that start in the year 2000. While exact years are given here, the data are more correctly referred to in decadal scales (i.e., "by 2050" instead of "in 2046"). The yearly data were created through a spline interpolation between known decadal data points.

When High Tide Flooding Becomes a Problem

As sea level rises, high tide flooding and impacts will occur more frequently. Currently in Charleston, SC, the high tide flooding threshold is 1.9 feet MHHW, which occurs _6__ days each year and which may or may not be a problem. At 185 days a year, it does become a problem.

In the future:

- Under the **Low** sea level rise scenario, high tide flooding will occur less than 185 days a year.
- Under the **Intermediate-Low** sea level rise scenario, high tide flooding will occur 185 or more days a year by 2095.
- Under the **Intermediate** sea level rise scenario, high tide flooding will occur 185 or more days a year by 2059.
- Under the **Intermediate-High** sea level rise scenario, high tide flooding will occur 185 or more days a year by 2049.
- Under the **High** sea level rise scenario, high tide flooding will occur 185 or more days a year by 2039.
- Under the **Extreme** sea level rise scenario, high tide flooding will occur 185 or more days a year by 2036.

NOTE: This analysis is based on sea level rise curves that start in the year 2000.

Significant Flood Events Occurring More Often

Charleston, SC will also experience a change in the return period of more significant coastal flooding events. Currently, the 1% chance (1 in 100 year) water level is 4.27 ft MHHW. With 1.64 ft of sea level rise, this 1% chance water level will become the 10% chance (1 in 10 year) water level of 2.63 ft MHHW.

- Under the Low sea level rise scenario, the 1% water level becomes the 10% water level after 2100.
- Under the Intermediate-Low sea level rise scenario, the 1% water level becomes the 10% water level in 2077.
- Under the Intermediate sea level rise scenario, the 1% water level becomes the 10% water level in 2051.
- Under the Intermediate-High sea level rise scenario, the 1% water level becomes the 10% water level in 2040.
- Under the High sea level rise scenario, the 1% water level becomes the 10% water level in 2034.
- Under the Extreme sea level rise scenario, the 1% water level becomes the 10% water level in 2031.

NOTE: This analysis is based on sea level rise curves that start in the year 2000. While exact years are given here, the data are more correctly referred to in decadal scales (i.e., "by 2050" instead of "in 2046"). The yearly data were created through a spline interpolation between known decadal data points. In addition, the 1% annual water level values do not necessarily correspond to the base flood elevations defined by the Federal Emergency Management Agency.

References

NOAA Technical Report NOS CO-OPS 086 - Patterns and Projections of High Tide Flooding

NOAA Technical Report NOS CO-OPS 086 - Data: Patterns and Projections of High Tide Flooding (CSV)

NOAA Technical Report NOS CO-OPS 083 - Global and Regional Sea Level Rise Scenarios for the U.S.

NOAA Technical Report NOS CO-OPS 083 - Data: Global and Regional Sea Level Rise Scenarios for the U.S. (CSV)

NOAA Technical Report NOS CO-OPS 067 - Extreme Water Levels of the United States: 1893-2010

CO-OPS API for Data Retrieval

U.S. Army Corps of Engineers Sea-Level Change Curve Calculator

City of Charleston, Department of Public Services, Infrastructure Improvement Projects

Department of Transportation - Applying Climate Change Information to Hydrologic and Hydraulic Design of Transportation Infrastructure